Before the
# FEDERAL COMMUNICATIONS COMMISSION
Washington, DC  20554

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| In the Matter of | ) |
| | ) |
| Revision of Part 15 of the Commission's Rules | ) |
| Regarding Ultra-Wideband Transmission | ) |
| Systems | )     ET Docket 98-153 |
| | ) |
| To:  The Commission | ) |

## REPLY COMMENTS OF ROCKWELL COLLINS, INC.

Rockwell Collins, Inc. ("Rockwell Collins") a wholly-owned subsidiary of Rockwell International Corporation, hereby respectfully files electronic Reply Comments in the above-referenced proceeding,[1] which seeks to investigate and possibly permit the operation of ultra-wideband ("UWB") radio systems on an unlicensed basis under Part 15 of the Commission's rules.

As pointed out in the Comments filed in the above docket, Rockwell Collins is a major manufacturer and integrator of avionics and Global Positioning System (GPS) equipment and systems for civilian and military markets.  Rockwell Collins has long been engaged in assisting government and industry in developing solutions to external interference within the GPS frequencies.  Therefore, Rockwell Collins is a party with an interest in the outcome of this proceeding.

### INTRODUCTION

In many comments filed in response to the Commission's NPRM in the above docket, numerous parties, including Rockwell Collins, agree that UWB is a promising technology that

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[1] See *In the Matter of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, ET Docket No. 98-153, Notice of Proposed Rulemaking, 65 Fed. Reg. 37332 (June 14, 2000) ("NPRM").

could provide significant benefits to consumers and government services.[2]  However, a significant number of industries affected by UWB technologies rightfully point out the Commission must ensure that any use of UWB technology should not cause harmful interference to existing spectrum users such as GPS.[3]

## DISCUSSION

Rockwell Collins reaffirms its Comments submitted on September 12, 2000.  Rockwell Collins recognizes that UWB devices may offer significant benefits for public safety, businesses and consumers and understands the Commission's desire to move forward the regulatory process enabling UWB technology deployment.  As noted, Rockwell Collins is studying UWB technology for possible use in future avionics communications, navigation, or surveillance applications with appropriate electromagnetic compatibility measures.

Rockwell Collins supports and encourages the Commission's stated commitment "to ensuring that safety of life services, such as GPS, are protected against harmful interference."[4] To ensure this protection, Rockwell Collins and others[5] strongly believe the Commission must allow sufficient time for adequate testing and analysis of the potential of UWB devices for

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[2] *See* Comments of METRO Area Agency on Aging; Comments of Senior Citizens, Inc.; Comments of Senator Lott; Comments of the International Association of Fire Chiefs.  There were very similar letters by numerous fire departments and health care facilities supporting the potential applications of UWB.

[3] *See* Comments of Boeing at 3; Comments of the Satellite Industry Association at 3; Comments of the Aeronautical Radio, Inc. ("ARINC") and the Air Transport Association ("ATA") at 4-8; Comments of Lockheed Martin at 1; Comments of QUALCOMM at 4, Comments of SiRF Technology ("SiRF"); Comments of GARMIN at 4; Comments of the US GPS Industry Council at 11; Comments of the National Association for Amateur Radio ("ARRL") at 6.

[4] See Separate Statement of Chairman William E. Kennard, FCC 00-29, ET-Docket No. 98-153, Released July 14, 2000.

[5] *See* Comments of Sirius Satellite Radio, Inc. ("Sirius") at 23-26; Comments of the Department of Transportation at 2, 9-13 discussing the myriad of testing issues which need to be solved before appropriate data can be acquired; Comments of Wireless Communications Association at 3-6; Comments of National Business Aviation Association at 2; Comments of Metricom at 6; Comments of US GPS Industry Council at 35; Comments of QUALCOMM at 3; Comments of Lockheed Martin at 4-5; Comments of SiRF at 4; Comments of GARMIN at 8; Comments of ARRL supra at 10; Comments of Boeing supra at 4.

interfering with GPS signals and other safety service signals operating in the restricted bands (47 CFR §§15.205) prior to any final rulemaking.

Although there are a significant number of issues presented in the many Comments filed, Rockwell Collins wishes to focus upon only two key issues.

**1. The Commission must account for the cumulative effect of UWB emissions in any final rule.**

Rockwell Collins would like to reiterate its own comments and echo those of other parties who believe the Commission should carefully study the potential cumulative effect of UWB emissions upon GPS and other restricted bands.[6] GPS signals are satellite space-to-Earth signals which are less powerful at the earth's surface than most terrestrial wireless applications.[7] Therefore, GPS applications must utilize sensitive receivers to make measurements and obtain data from the satellite downlink signals. In addition, GPS receivers are mobile in many key applications and use omni-directional antennas which have less ability to reject interference than directional antennas.[8]

> **A. The propagation path losses, and, therefore, the radio frequency interference (RFI) effects, from any one UWB emitter in a horizontally distributed group of UWB emitters to a vertically separated victim receiver is nearly equal to the interference from the closest UWB emitter.**

The Commission has tentatively concluded that the cumulative impact of multiple UWB devices appears to be negligible and that only the closest transmitter placing an emission on the frequency of concern is important.[9] Rockwell Collins believes this conclusion is incorrect. In our initial Comments, Rockwell Collins stated that "there is a very real probability that several

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[6] *See* Rockwell Collins Comments at 6; Comments of SIA at 5; Comments of Lockheed Martin at 6 (noting that the Commission's findings that multiple co-located UWB devices would cause no significant rise in the RF noise floor is based upon papers authored by UWB advocates); Comments of GARMIN at 5; Comments of ARRL at 13; Comments of the US GPS Industry Council at 33; Comments of Sirius at 9, Comments of Lucent Technologies. at 7.
[7] *See* Comments of Sirius at 10.
[8] Id.
[9] NPRM supra at ¶47.

tens of devices could occupy a space roughly 30 feet in diameter.[10]"  The comment continues by

stating that "all UWB emitters [within that space] will have a path loss within 0.1 dB of one

another to a GPS receiver 100 feet above them (the Category I aircraft precision approach

scenario of RTCA/DO-235, Appendix A).[11]"  The first aspect of the statement (tens of UWB

devices in a 30 foot circle) derives from the potential UWB use in land vehicles for

communication and radar-based collision avoidance applications.[12]  The diameter of the circle is

roughly the width of a 3-lane roadway.  As many as 6 average sized cars, each with several

UWB devices (e.g., 1 communication and 4 radar devices) could occupy that amount of space in

a traffic jam.  The second aspect of the statement (all emitters within the 30 foot circle would

have a path loss within 0.1 dB of one another to a GPS receiver 100 feet overhead) can be

derived from geometric considerations.[13]  The 0.1 dB factor is rather arbitrary and chosen only to

represent a small (2.3%) path loss difference.  Examination of the basic equation shows that if

the allowed path loss difference were chosen to be 0.5 dB (12.2%), the circle containing those

emitters would grow to a 70 foot diameter.  The larger circle could, of course, contain many

more emitters.  The numerical examples above demonstrate the relatively slow increase in path

loss to a vertically separated victim receiver for RFI sources in the same horizontal plane with

increasing offset from the closest source.  Given the relative insensitivity of path loss to

horizontal separation from the closest source, each RFI source within the group has the potential

to contribute a nearly equal amount to the RFI at the receiver.

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[10] *See* Rockwell Collins Comments supra at 6.
[11] Id.
[12] NPRM supra at ¶11, 12.
[13] See Appendix A attached hereto and made a part hereof.

**B. The cumulative RFI impact to GPS and other receivers from multiple UWB devices can exceed the simple additive impact under certain circumstances.**

Rockwell agrees with the comments of Lucent Technologies on the cumulative RFI effect from multiple UWB devices[14] and offers in these reply comments some additional explanation. It is a well known fact from linear circuit theory that the arrival of a very short duration pulse (e.g. a UWB pulse) triggers a transient or natural response in a conventional circuit. The transient response for a receiver with an input preselector filter will likely be dominated by the transient response of the filter.[15] When several similar UWB emitters are in range of the receiver, Lucent states "the RF power peaks will cluster or coincide in time as well as frequency.[16]" Rockwell Collins suggests the RFI impact mechanism in the receiver is the overlap in time of transient responses from the pulses of individual UWB emitters. Rockwell Collins further suggests that transient response from one UWB pulse will not yet decay away when a pulse from another UWB emitter triggers a new response. The combined RFI effect from several relative low pulse repetition frequency (PRF) UWB emitters could thus exceed that of a single high PRF emitter. This combined RFI transient response is likely to be difficult to quantify and probably not simply the addition of individual emitter RFI effects. The effect should be the subject of extensive analytical and experimental investigation.

The discussion in Part A above has demonstrated that path loses to a victim receiver separated vertically from a group of horizontally distributed RFI sources can be nearly equal to that for the closest source under certain circumstances. In Part B we have offered sound reasoning as to why the cumulative RFI impact to GPS and other receivers from multiple UWB devices can exceed the simple additive impact under certain circumstances. For these reasons,

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[14] *See* Comments of Lucent Technologies, Inc. at 5, 7.
[15] *See* Appendix B attached hereto and made a part hereof.
[16] Lucent Comments supra at 7

the Commission must account for the cumulative interference effect of multiple UWB emitters in its rule making.

## 2. The Commission should accept testing data for at least 120 days after the stated NPRM data posting deadline.

As shown above, there is a complex interaction between UWB pulses and transient responses of GPS receivers. This interaction should be the subject of extensive analytical and experimental investigation. Rockwell Collins again urges the Commission to provide interested parties sufficient time to perform adequate testing of the potential effects of UWB devices on GPS receivers. The Commission has stated that many UWB devices cannot avoid transmitting into restricted frequency bands and cannot operate under current regulations.[17] Yet, by rushing the essential RFI investigation, the Commission appears willing to compromise safety-of-life services dependent upon GPS and other safety services utilizing restricted bands in order to allow widespread use of a technology whose effects are not yet fully understood.

At the present time, the only test results available are from the University of Texas Applied Research Labs[18] and Stanford University.[19] The initial University of Texas data are raw receiver channel measurement streams from non-aviation GPS receivers and take up approximately 6.5 Gigabytes of memory space. Reducing this data to the state required for subsequent RFI analysis will take significant time to perform properly. Although the Stanford data is only for one aviation precision approach receiver, it indicates UWB devices can interfere with GPS receivers.[20] Therefore, it is essential that additional aviation precision approach GPS receivers are tested to verify the Stanford results. Since the additional testing has not yet begun,

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[17] NPRM supra at ¶7, 23.
[18] *See* Ex Parte Notice by Miguel Cardoza of the University of Texas, October 10, 2000.
[19] Ming Luo, et al, "Interference to GPS from UWB Transmitters," Institute of Navigation GPS 2000 Conference, 19-22 Sept., 2000, Salt Lake City, UT, paper # F2-3; RTCA Report supra at 11-14.
[20] RTCA Report supra at 31.

it clearly will not be completed by the October 30 deadline. In its initial comments Rockwell Collins noted that all the GPS receiver RFI testing is being done with L1 receivers and additional time is needed to investigate the new GPS L5 receiver effects.[21] Also, no testing is apparently being done yet on military GPS receivers. Time should be allowed to assess the impact to current military receivers that use the L1 C/A signal.

Many parties commented that further testing is necessary.[22] However, the Commission has put forth preliminary proposals to permit low-power, mass market UWB devices to operate on an unlicensed basis; place no restrictions on UWB devices operating above 2 GHz; and allow ground-penetrating radars to operate in frequencies below 2 GHz.[23] Given the limited amount of testing data available today, permitting the mass market of UWB devices is not prudent.

Rockwell Collins strongly urges the Commission to protect public safety and those frequencies providing safety-of-life services. It would be premature to allow unlicensed use of UWB devices before test results are compiled and thoroughly analyzed.

### Summary

Rockwell Collins is very concerned the Commission is not taking into account the cumulative effect multiple UWB emissions have on a GPS receiver. Rockwell Collins recognizes that doing so complicates the issue. However, when human lives and safety-of-life services could be at risk, waiting until more thorough testing and analyses is completed is the prudent action. Testing is being conducted as these Reply Comments are being written. However, significantly more testing needs to be done on the different kinds of UWB emitters and their complex interaction with GPS receivers. Further, the test results should be thoroughly analyzed before any final decision with respect to UWB devices is made.

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[21] Rockwell Collins supra at 3.
[22] *See* Footnote 5.

For these reasons, the Commission will serve the public interest well by allowing

additional time to test and analyze the interference potential of UWB emitters on the safety-of-

life services and the licensed users of the spectrum.  Please direct any questions to Joseph

Cramer at 703-516-8213.

Respectfully submitted,

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[23] *See* NPRM at ¶18, 25, 27.

# Appendix A

## Derivation of the Size of Circle of Equal Path Loss in an Aviation GPS Precision Approach
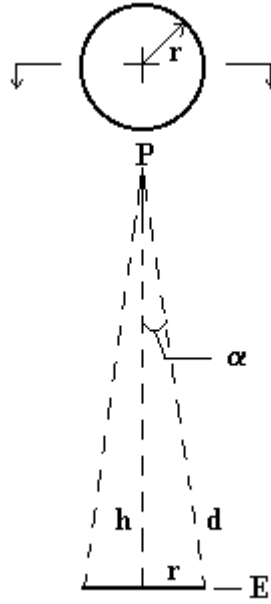
## Interference Scenario



**Figure 1. Top and Side Cross-section Views of Aircraft Overhead Pass of Interference Sources**

In the above figure point P represents the position of the airborne GPS receive antenna and the surface E represents the plane containing the interference sources (UWB emitters in this case).

Let  $h =$  the minimum distance from P to the plane E,
$d =$  the distance from points on the surface E whose radio propagation path loss differs from the minimum loss at distance h by a fixed ratio value,
$r =$  the radius of the circle containing the points of the fixed path loss ratio,
$\alpha =$  the angle between line h and line d.

If free space propagation is assumed the radio propagation path loss is proportional to the inverse square of the distance between transmitter and receiver. Defining *LR* as the ratio of path loss for distance, *d*, to that for the minimum distance, *h*, as *LR* and applying the inverse square relationship yields:

$$LR = d^2 / h^2 \qquad \text{or } d^2 = LR \bullet h^2 \qquad \text{(Eqn 1).}$$

Since d, h, and r form a right triangle, by the Pythagorean Theorem :

$$r^2 + h^2 = d^2 \qquad \text{or } r^2 = d^2 - h^2 \qquad \text{(Eqn. 2)}.$$

Substituting Eqn 1 into Eqn. 2 and solving for the circle radius, $r$, in terms of $h$ and $LR$ yields:

$$r = h \bullet \sqrt{(LR - 1)} \qquad \text{(Eqn. 3)}.$$

By basic trigonometric definitions, $\cos(\alpha) = h / d$. When when expressed in terms of loss ratio, $LR$, and solved for $\alpha$ yields:

$$\alpha = \cos^{-1}(1/\sqrt{(LR)}) \qquad \text{(Eqn. 4)}.$$

The loss ratio, $LR$, as a numeric factor is related to its equivalent in decibel terms, $LR_{dB}$, by:

$$LR = \text{antilog}_{10}(LR_{dB} / 10) \qquad \text{(Eqn. 5)}.$$

Thus loss ratios in decibels of 0.1 dB and 0.5 dB correspond by Eqn. 5 to numeric loss ratio values of 1.0233 and 1.1220, respectively. Substitution of those loss ratio values together with a minimum separation distance to the GPS receiver, $h$, of 100 feet into Eqn. 3 yields values for the circle radius $r$ of:

$$r = 100 \bullet \sqrt{(1.0233 - 1)} \quad = \quad \textbf{15.26} \text{ feet } (30.5 \text{ feet diam.}) \quad \text{and}$$

$$r = 100 \bullet \sqrt{(1.1220 - 1)} \quad = \quad \textbf{34.93} \text{ feet } (69.9 \text{ feet diam.}).$$

The same loss ratio values substituted into Eqn. 4 yield values for the half-cone angle $\alpha$ of:

$$\alpha = \cos^{-1}(1/\sqrt{(1.0233)}) \quad = \quad \textbf{8.68} \text{ degrees } \text{ and}$$

$$\alpha = \cos^{-1}(1/\sqrt{(1.1220)}) \quad = \quad \textbf{19.25} \text{ degrees}.$$

Note that the half-cone angle values are significantly small that the GPS antenna gain toward the interference sources at the base of the cone (within radius r of the cone base center) could be assumed to remain constant independent of actual source position. If there is any antenna gain variation over the lager sized (0.5 dB) cone base, the gain may actually increase with increasing distance from the cone base center and thereby offset the reduction of interference signal resulting from the increased path length..

**Appendix B**
Transient Response of a GPS RF Preselector Filter

Shown below are two time waveforms (Fig. B1) taken by Stanford University during their UWB RFI effects testing. The top trace shows a single UWB pulse at the input of the reference GPS L1 preselector. In the Stanford set-up the filter (1575.42 MHz center frequency, 24 MHz bandwidth, Fig. B2) is used as a bandwidth reference for the total input power measurement and it also represents the sort of filter in aviation active antenna unit that often precedes the receiver in a typical aircraft installation. The lower trace shows the filter output waveform, the transient response, is essentially a signal oscillating at the filter's center frequency with a duration essentially equal to the reciprocal of the filter bandwidth (stretched approximately 40 times the duration of the input pulse).
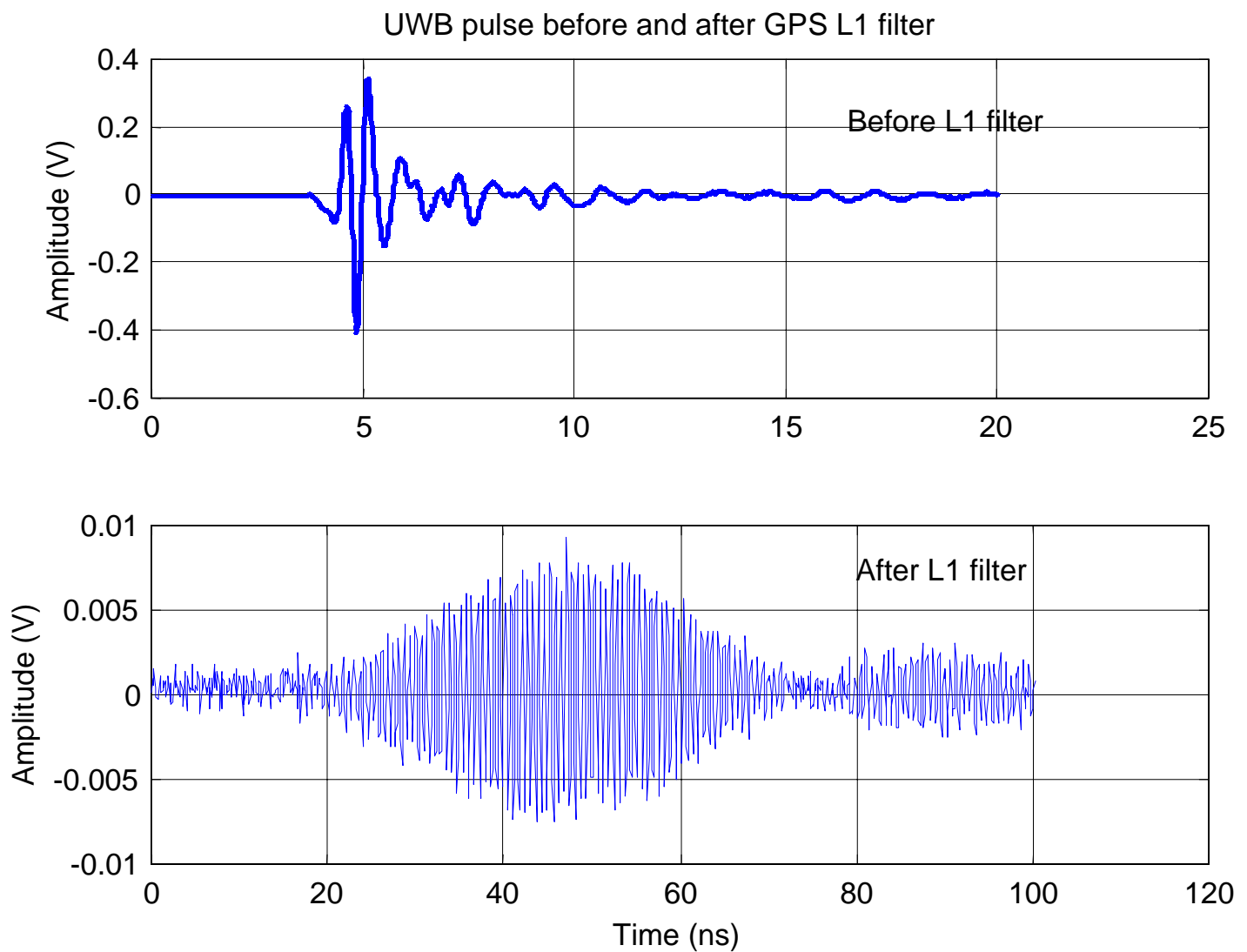
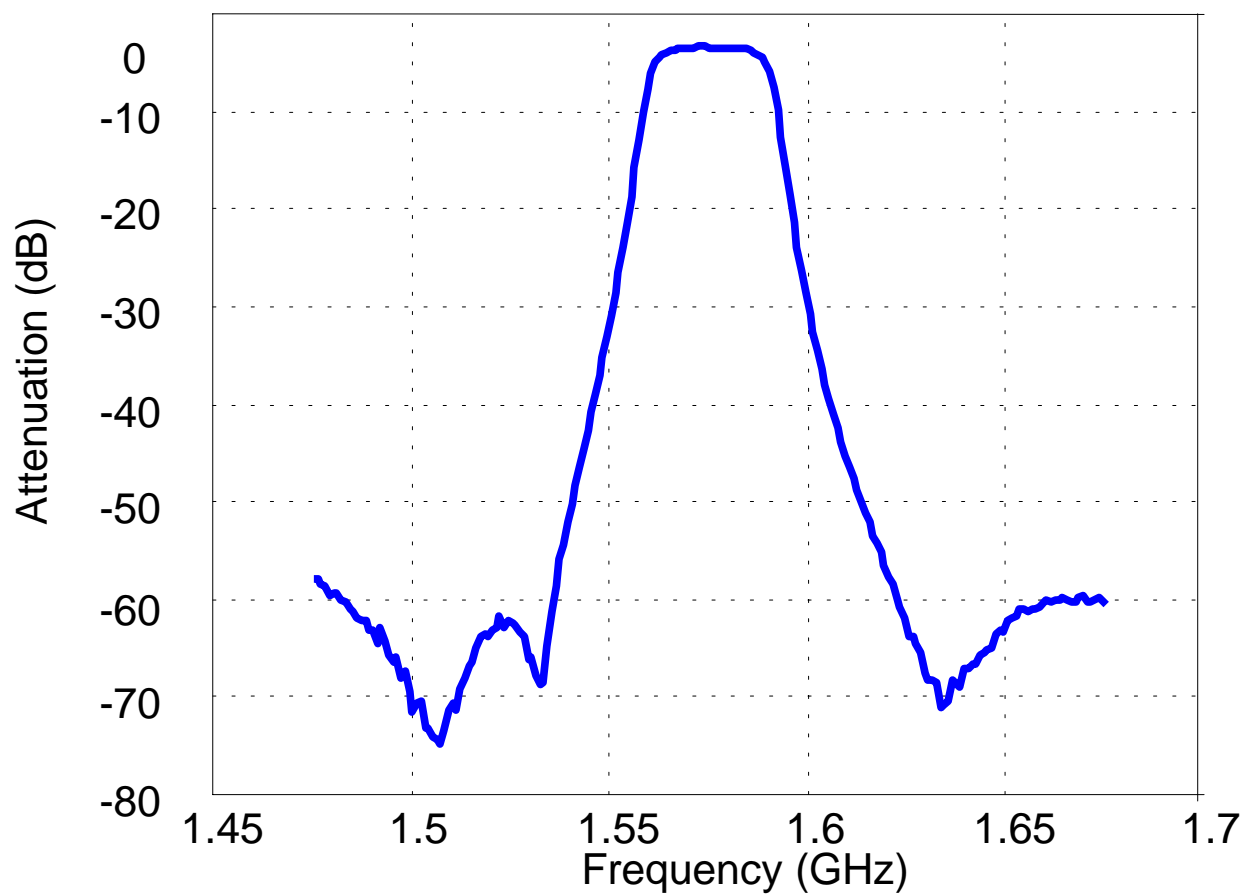

**Figure B1. GPS L1 Preselector Filter Input and Output Waveforms**

**Figure B2. GPS L1 Preselector Frequency Response**